Influence of the Ion Beam Current on Microstructures and Optical Properties of Al_2O_3 Thin Films by Oxygen Ion Beam Assisted Pulse Reactive Magnetron Sputtering

Zhimin Wang, Jinxiao Wang, Yi Wang, Kai Zhao, Xiaomei Su, Hu Wang, Yudong Feng*

Science and Technology on Surface Engineering Laboratory, Lanzhou Institute of Physics, Lanzhou 730000, China

Extended Abstract:

Al_2O_3 thin films was prepared in a self-designed ion beam assisted pulse reactive magnetron sputtering system, in which the films can be synthesized with sputtered aluminum under simultaneous oxidation with oxygen ions produced by ion source. A metallic aluminum target with the purity of 4N was employed which was a 560mm by 80mm rectangular area. The substrate holder was located 100mm away from the target surface. Argon gas of high purity (99.99%) grade was used as sputter gas and was bled to the substrate through aluminum tube. The gas mixture of oxygen and argon was imported in the ion source. Meanwhile the oxygen content was controlled by regulating the flow ratio of oxygen and argon. Prior to the deposition work, substrates were cleaned by Ar ion sputtering for 5 min to remove contaminant on the surface. During deposition, the substrate temperature was room temperature.

Fig. 1 shows the hysteresis behavior of cathode target with ion source operated at Va=200 V, Ia=1 A and without ion beam assistance. It can be seen that the hysteresis effect still appeared in the oxygen ion beam assisted process, and thus the cathode should be operated before the transition point from the metal mode to the metastable transition mode. In ion beam oxidation process, we should carry out the research of experimental parameters on microstructures and properties of the films. In the following, we showed the influence of ion beam current on microstructures and properties of Al_2O_3 thin films with other parameters fixed.

* Corresponding author. Tel.: +86931 4585045; fax: +86931 8265391.
E-mail address: fengyd2008@gmail.com.

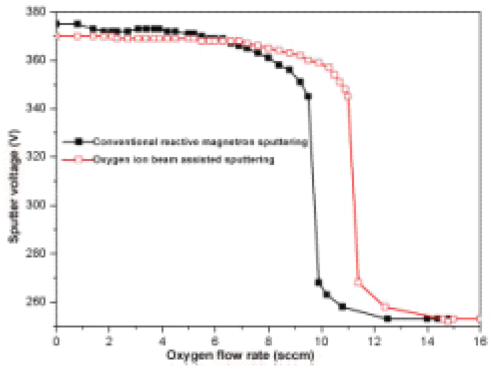

Fig. 1 Hysteresis behavior of oxygen ion beam assisted sputtering operated at *V*a=200 V, *I*a=1 A and conventional reactive magnetron sputtering.

XPS spectra of Al 2p photoelectrons measured from films are shown in Fig. 2 with a variation of the ion beam current from 0.25 A to 1 A. The spectrum could be separated into two Gaussian components which corresponded to metallic state at binding energy of 72.8eV and Al_2O_3 oxide state at binding energy of 74.7eV, respectively. Here it is noted that ion beam current could lead to significant influence on the composition of films. As the ion beam current increased, the intensity of aluminum form at lower binding energy wear off, and yet the intensity of Al_2O_3 form at higher binding energy strengthened, resulting that those two obvious peaks appeared in the Al 2p spectrum. And then the peak at lower binding energy gradually disappeared. In consequence, the Al 2p peak could be fitted with only one peak which shifted towards oxide state at higher binding energy with ion beam current increasing, showing that Al_2O_3 content in the film increased as the ion beam current increased. When the ion beam current increased up to 0.85 A, stoichiometrical Al_2O_3 thin films were successfully deposited. In addition, XRD measurements showed that all the Al_2O_3 films were amorphous.

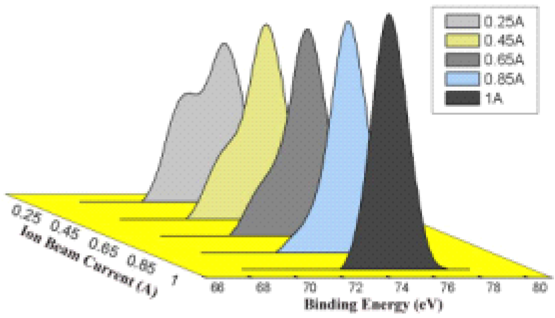

Fig. 2 XPS spectra of Al 2p photoelectrons measured from films deposited with a variation of the ion beam current from 0.25 A to 1 A.

Fig. 3 presents the transmittance spectrum of the Al_2O_3 films deposited as a function of ion beam current. It is quite obvious that the transmittance of the film deposited at lower ion beam current, i.e. ion beam current at 0.45 A, was far lower than the rest of the films deposited with higher ion beam current over the entire spectrum. It revealed that the film deposited at lower ion beam current at 0.45 A did not entirely oxide, finally forming metal-dielectric mixture with high absorption. When the oxygen content increased to 0.85 A, the transmittance spectrum of the films was consisted with theoretical optical spectrum, indicating the film was totally stoichiometric. During the oxygen ion beam assisted process, oxygen ion was sufficient for Al oxidization to form stoichiometrical Al_2O_3 thin films with the increase of ion beam current up to 0.85 A.

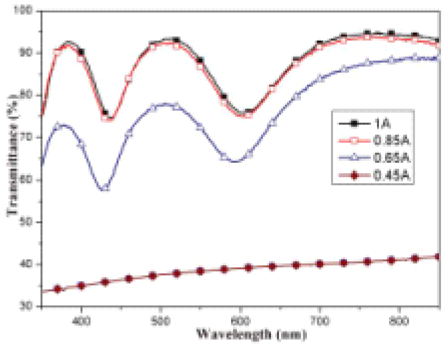

Fig. 3 Transmittance spectrum of the Al_2O_3 deposited as a function of ion beam current of the assist beam.

Fig. 4 plots the variation curve in the refraction index (n) and extinction coefficient (k) of Al_2O_3 films. It can be seen that Al_2O_3 thin films with stoichiometric at the ion beam current of 0.85 A had the highest refractive index and the lowest extinction coefficient. As the ion beam current further increased, refractive index became lower and extinction coefficient came into higher. The results could be contributed to redundant oxygen ion bombardment on growing surface, making unreactive oxygen ion covered by the following achieved Al atoms. The process increased the number of vacancies and interstitials in the film, resulting in optical property.

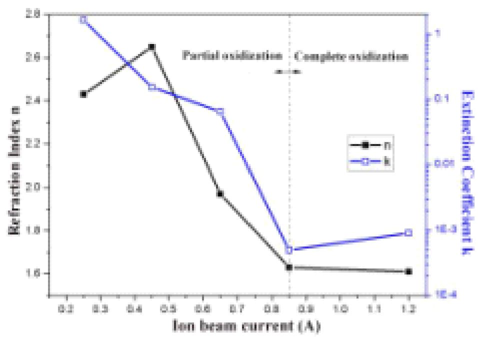

Fig. 4 Optical constants of the films with various ion beam current.

Fig. 5 presents deposition rate of the films with various ion beam current. The results show that the deposition rate was lower as the ion beam current less than 0.85 A. When the ion beam current increased up to 0.85 A, the deposition rate achieved the maximum. As further increasing the ion beam current, the deposition rate began to saturation. Therefore, it appears to be contributed that sufficient oxygen ion could react with Al atoms to form fully oxidized thin films with the ion beam current increased above 0.85 A, when oxygen in the films gradually saturated and the thickness of films became stabilization, resulting in saturation of the deposition rate.

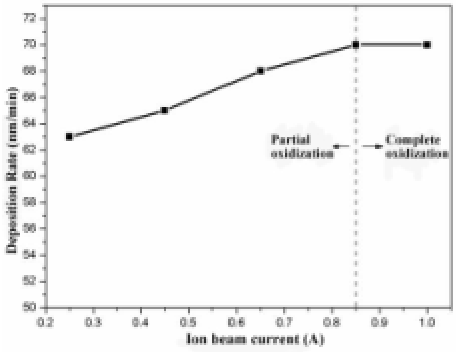

Fig. 5 Deposition rates of the films with various ion beam current.

In this paper, oxygen ion beam assisted pulse reactive magnetron sputtering has been used to deposit room temperature Al_2O_3 thin films on polyimide substrates with high deposition rate and the influence of ion beam current on microstructures, optical properties and deposition rate of Al_2O_3 thin films were investigated. The results show that the structure of the thin films deposited at various ion beam current were amorphous. Al_2O_3 thin films with stoichiometric at the ion beam current of 0.85 A had the highest refractive index and the lowest extinction coefficient. As the ion beam current further increased, refractive index became lower and extinction coefficient came into higher. The deposition rate slowly increased with the increase of ion beam current, achieved the maximum as ion beam current increased up to 0.85 A and then saturated with further increasing the ion beam current.